Safety and Airspace Regulation Group

Unmanned Aircraft Systems

Rotary Wing Swarm Operations – Visual Line of Sight – Requirements, Guidance & Policy

CAP 722E

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Contents

Revision history

First edition — July 2020

This is the first edition of this document.

Foreword

Aim

The aim of this document is to enable UAS operators to understand the requirements that must be met as part of an application for operational authorisations related to rotary wing UAS swarm operations in visual line of sight (VLOS).

It will indicate which volumes of the operating safety case (OSC) should address each requirement.

For more guidance on the OSC and the application process see CAP 722A and the UAS application process webpage here.

In advance of further changes to this document, updated information is contained on the CAA website via UAS Unit web pages.

Content

This CAP covers three areas. Chapter 2 describes the basic requirements for all rotary wing VLOS swarms. Chapter 3 provides additional information on airspace, public displays, and notification. Finally, Appendix A is a summary of the requirements listed in Chapter 2.

The content of CAP 722E does not replace the current civil regulations. Wherever possible, this guidance has been harmonised with any relevant emerging international UAS regulatory developments where available.

Availability

The latest version of CAP 722E can be located within the publications section of the CAA website.

Updated information can be found within the latest updates section of the CAA website's UAS webpages.

The CAA also provides a more general aviation update service via the SkyWise system, which can be filtered by subject matter for relevant UAS related information.

Structure

CAP 722E, sits within the CAP 722 suite of UAS guidance and policy, which can be found here.

This document is structured as follows:

CAP 722E

Point of contact

Unless otherwise stated, all enquiries relating to CAP 722E must be made to:

For queries relating to the content of CAP 722E:

UAS Unit
CAA
Safety and Airspace Regulation Group
Aviation House
Beehive Ring Road
Crawley
West Sussex
RH6 0YR

E-mail: uavenquiries@caa.co.uk

For matters concerning operations or approvals:

Shared Service Centre (UAS)
CAA
Aviation House
Beehive Ring Road
Crawley
West Sussex
RH6 0YR

Telephone: 0330 022 1908
E-mail: uavenquiries@caa.co.uk

Abbreviations and glossary of terms

The terminology relating to UAS operations continues to evolve and therefore the abbreviations and glossary of terms sections are not exhaustive. The terms listed below are a combination of the emerging ICAO definitions and other 'common use' terms which are considered to be acceptable alternatives.

Abbreviations

A

ADS-B	Automatic dependent surveillance broadcast
AGL	Above ground level
ALARP	As low as reasonably practicable
ANO	Air Navigation Order
AR Ops	Airspace Regulation Operations (Civil Aviation Authority)

B

BVLOS	Beyond visual line of sight

C

CAA	Civil Aviation Authority
C2	Command and control

F

FRZ	Flight restriction zone

N

NOTAM	Notice to airmen

O

OSC	Operating safety case

R

RF	Radio frequency
RPA	Remotely piloted aircraft

U

UA	Unmanned aircraft
UAS	Unmanned aircraft system(s)

V

VLOS Visual line of sight

Glossary of terms

A

Aircraft – Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the Earth's surface.

Air Navigation Order (ANO) – The legal document, established as a UK Statutory Instrument (SI) that is made for the purposes of regulating air navigation within the United Kingdom.

B

Beyond visual line of sight (BVLOS) – An operation in which the remote pilot or RPA observer does not use visual reference to the unmanned aircraft in the conduct of flight.

C

Command and control (C2) link – The data link between the remotely piloted aircraft and the Command Unit for the purposes of managing the flight.

Concept of operations – Describes the characteristics of the organisation, system, operations, and the objectives of the user.

Command unit – The equipment or system of equipment to control unmanned aircraft remotely as defined in point 32 of Article 3 of Regulation (EU) 2018/1139 which supports the control or the monitoring of the unmanned aircraft during any phase of flight, with the exception of any infrastructure supporting the command and control (C2) link service.

Note: In other UAS documents, Remote Pilot Station or Ground Control Station is listed as the preferred term. However, Command Unit is now the accepted term and other documents will be updated in due course.

Contingency volume – Zone between the boundary of the flight volume and the emergency buffer.

E

Emergency buffer – Zone outside the operational volume. If UA enters the emergency buffer, the emergency response plan must be carried out.

F

Flight restriction zone (FRZ) – Airspace of defined dimensions around a protected aerodrome (as defined in the Air Navigation Order, Article 94) within which the permission of the relevant ATS unit or aerodrome operator, as appropriate, is required before a small unmanned aircraft flight can take place.

Flight volume – The zone containing the planned operation, within which the UA must remain for continued safe operation.

L

Latency – This is defined by the time it takes for a request to travel from the transmitter (Command Unit) to the receiver (UA) and for the receiver to process that request. This is the total round-trip time from the Command Unit to the UA and back again. In reliable two-way communication systems, latency limits the maximum rate that information can be transmitted.

Lost C2 link – The loss of command and control link with the remotely piloted aircraft such that the remote pilot can no longer manage the aircraft's flight.

O

Operator – See UAS operator.

Note: In the context of remotely piloted aircraft, an aircraft operation includes the remotely piloted aircraft system.

Operating safety case (OSC) – Methodology used to apply to the CAA for a permission or exemption to operate a UAS within the UK.

Operational authorisation – A document issued by the CAA that authorises the operation of an unmanned aircraft system, subject to the conditions outlined within the authorisation, having taken into account the operational risks involved.

Operational volume – The zone containing the flight volume and the contingency volume.

R

Recovery area – An alternative area identified for the purpose of landing the swarm in the event of an emergency.

Remote pilot – A natural person responsible for safely conducting the flight of an unmanned aircraft by operating its flight controls, either manually or, when the unmanned aircraft flies automatically, by monitoring its course and remaining able to intervene and change the course at any time. Regulation (EU) 2018/1139.

Note: Within ANO 2016, article 94G the "remote pilot", in relation to a small unmanned aircraft, is an individual who:

(i) operates the flight controls of the small unmanned aircraft by manual use of remote controls, or

(ii) when the small unmanned aircraft is flying automatically, monitors its course and is able to intervene and change its course by operating its flight controls

In this document, the term 'remote pilot' is used for all sizes of unmanned aircraft, hence the first definition is applicable.

Remotely piloted aircraft (RPA) – An unmanned aircraft which is piloted from a remote pilot station.

Remote pilot station (RPS) – See command unit.

S

Sterile ground area – An area on the ground or water within which only people that are involved in the operation are permitted.

Swarming – Operation of more than one UA which are controlled collectively rather than individually.

U

Unmanned aircraft (UA) – Any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board.

Note: RPA is considered a subset of UA.

Unmanned aircraft system (UAS) – An unmanned aircraft and the equipment to control it remotely.

Note: The UAS comprises individual 'System Elements' consisting of the Unmanned Aircraft (UA) and any other System Elements necessary to enable flight, such as a Command Unit, Communication Link and Launch and Recovery Element. There could be multiple UA, Command Units or Launch and Recovery Elements within a UAS.

Unmanned aircraft system operator (UAS operator) – Any legal or natural person operating or intending to operate one or more UAS.

V

Visual line of sight (VLOS) operation – Means a type of UAS operation in which, the remote pilot is able to maintain continuous unaided visual contact with the unmanned aircraft, allowing the remote pilot to control the flight path of the unmanned aircraft in relation to other aircraft, people and obstacles for the purpose of avoiding collisions.

CHAPTER 1 | General introduction

1.1 Policy

Unmanned aircraft systems (UAS) operating in the UK must meet at least the same safety and operational standards as manned aircraft when conducting the same type of operation in the same airspace.

As a result, when compared to the operations of manned aircraft of an equivalent class or category, UAS operations must not present or create a greater hazard to persons, property, vehicles or vessels, either in the air or on the ground.

However, with unmanned aviation the primary consideration is the type of operation being conducted, rather than who or what is conducting it, or why it is being done. As there is 'no one on board' the aircraft, the consequences of an incident or accident are purely dependent on where that incident/accident takes place. The CAA's focus is therefore on the risk that the UAS operation presents to third parties, which means that more effort or proof is required where the risk is greater.

Swarming is the operation of more than one unmanned aircraft (UA) controlled collectively rather than individually.

1.2 Scope

This document applies to civilian UAS operators wishing to apply for authorisation to operate rotary wing UA as a swarm within visual line of sight (VLOS).

This guidance applies to applications for a single swarm operation at a specific site or for applications for multiple operations at different sites. The OSC will be more straightforward for single operations. The OSC's complexity will increase significantly if the applicant wishes to obtain authorisation to operate a swarm at multiple sites.

Operations of swarms involving fixed wing UA, or flight beyond visual line of sight (BVLOS), are outside the scope of this document. In these cases, UAS operators should contact the CAA directly to discuss further (see page 6 for contact details).

This document describes the requirements for an authorisation to operate a swarm. It also provides guidance for completing the OSC.

1.3 Editorial practices

In this document the following editorial practices apply:

- '**Must**' / '**must not**' indicates a mandatory requirement.
- '**Should**' indicates a strong obligation (in other words, a person would need to provide

clear justification for not complying with the obligation).

- '**May**' indicates discretion.
- 'Describe' / 'explain' indicates the provision of logical argument and any available evidence that justifies a situation, choice, or action.

Requirements that **must** be included within the OSC are underlined within the text of Chapter 2 and Appendix A. For example:

'The remote pilot(s) **must** be competent to carry out UA swarm operations.'

CHAPTER 2 | Basic requirements for all rotary wing VLOS swarms

The following requirements **must** be included in the OSC submitted to the CAA for authorisation of UA swarm operations.

This chapter **must** be read in conjunction with CAP 722A Unmanned Aircraft Systems Operations in UK Airspace – Operating Safety Cases.

For swarming operations, the applicant **must** prepare and submit all 3 volumes of the OSC. Particular attention **should** be paid to the Volume 3 risk assessment. Identified safety risks **must** be specific to the proposed operation and **must** be mitigated to an acceptable level.

2.1 OSC Volume 1 – Operations Manual

The operational requirements listed below **must** be included in Volume 1 of the OSC.

Any safety risks identified under any of these headings, **must** be mitigated to a tolerable and ALARP level.

Volume 3 of the OSC **must** explain why all safety risks identified in Volume 1 are tolerable and ALARP.

This list is not exhaustive and must be read in conjunction with CAP 722A.

2.1.1 Remote pilot competence

The remote pilot(s) **must** be competent to carry out UA swarm operations.

Explain why the operator is satisfied that the remote pilot(s) is competent enough to comply with the conditions of an authorisation.

Explain how the qualifications and experience of the remote pilot(s) ensure they are competent to carry out the swarming operations.

2.1.2 Support crew competence

The support crew **must** be competent to support UA swarm operations.

Explain how the qualifications and experience of the crew ensure they are competent to support swarming operations. An example of a support crew member is a visual observer who keeps a lookout for other airspace users.

2.1.3 Line of sight

The swarm operation **must** be carried out within VLOS.

Application for approval of a BVLOS swarm operation is outside the scope of this document.

2.1.4 Dimensions of the flight volume

The planned flight of the swarm **must** remain within the flight volume.

The upper limit of the flight volume **must** be kept as low as possible and only be as high as necessary to accommodate the planned flight of the swarm.

The horizontal dimensions of the flight volume **must** be sufficient to accommodate the planned flight of the swarm.

The flight volume **must** encompass the entire swarm and its planned movement, with sufficient allowance for any operational movement around the flight path.

State the dimensions and location of the flight volume.

2.1.5 Swarm height

The height of the swarm **must** be monitored and accurately measured.

The height of the swarm **should** be based on the height of the highest individual UA at any time during the flight.

Explain how the swarm height is measured and monitored during the flight, and how accuracy is assured.

2.1.6 Airspace

Appropriate airspace **must** be used for the swarm operation.

The OSC **must** contain all the information listed below:

- State the dimensions and location of the flight volume (see paragraph 2.1.4 and paragraph 3.2, figures 1 and 2).
- State the dimensions and location of the contingency volume and emergency buffer (see paragraph 3.2, figures 1 and 2).
- State the class of airspace where the swarm is to be conducted.
- State whether any additional permission is required to operate in the proposed airspace; for example, if the operation is within an FRZ.
- Explain how any additional permission will be applied for.

2.1.7 Notification

All swarm flights **must** be notified in advance to CAA Airspace Regulation Operations (AR Ops).

UAS operators **must** provide details of any swarm flight to AR Ops arops@caa.co.uk at least 28 days before the date of the flight using Form DAP 1918 from CAP 736. (See paragraph 3.3 for additional guidance.)

The CAA will issue any NOTAM that is required, following submission of a DAP 1918 request.

State your notification procedures.

2.1.8 Weather conditions

The swarm operation **must** only be conducted in the appropriate weather conditions.

State the weather limits for the operation and explain how the weather will be monitored during the operation.

2.1.9 Go/no-go criteria

Go/no-go and abort criteria **must** be clearly defined for the swarm operation.

State the go/no-go criteria for the operation.

2.1.10 Emergency abort

The decision to abort the swarm **must** be made quickly and reliably enough, in response to an emergency, to prevent harm to people.

State who will make real-time decisions to abort the flight and what qualifies them to make the decision. This person **must** be physically present at the site of operation while the swarm is in flight.

Explain how the decision to abort will be made quickly and reliably to effectively intervene in an emergency to prevent harm.

State the abort conditions which, if reached, would lead to an immediate and safe termination of the operation. Explain the abort procedures which are in place to enable this decision.

State that the abort decision will always be free from commercial or contractual pressure.

2.1.11 Operating procedures

Operating procedures **must** be clearly defined for the swarm operation.

The OSC **must** state and explain the operating procedures as necessary, including the:

- normal operating procedures
- lost C2 link procedures and protocols
- contingency procedures, including:
    - UA excursion from the flight volume
- emergency procedures, including:
    - aircraft incursion into the operational volume
    - UA excursion from the operational volume

    - uninvolved third parties crossing the crowd line and entering the sterile ground area
- emergency response plan (ERP).

2.1.12 Illumination of take-off, landing and nominated recovery areas

The take-off, landing and nominated recovery areas **must** be sufficiently illuminated.

Use of recovery areas is recommended.

Explain how the take-off, landing and any nominated recovery areas are sufficiently illuminated to ensure safe operation of UA when using the areas.

2.1.13 Insurance

The insurance policy **must** provide adequate cover for swarming operations.

Include copies of the relevant insurance documents.

2.1.14 Projection or dropping of articles

The safety risks associated with the projection or dropping of articles **must** be tolerable and ALARP.

Permission from the CAA **must** be obtained for any dropping of articles from a UA.

Explain what articles will be projected or dropped.

Explain how articles will be projected or dropped.

Explain how the safety risk is tolerable and ALARP in Volume 3 of the OSC.

2.1.15 Overflight of uninvolved third parties

The swarm **must not** overfly uninvolved third parties.

See CAP 722A Appendix A, Overflight of Uninvolved Third Parties, for more information.

Explain how the overflight of uninvolved people will be avoided.

Explain how the safety risk is tolerable and ALARP in Volume 3 of the OSC.

2.1.16 Swarms for public display – sterile ground area

A sterile ground area **must** be in place for the operation.

Uninvolved third parties **must not** be present in the sterile ground area.

The sterile ground area is the entire ground or water area covered by the flight volume, the contingency volume and the emergency buffer. (See paragraph 3.2, figures 1 and 2.)

State the dimensions and location of the sterile ground area.

2.1.17 Swarm for public display – crowd line position

A crowd line **must** be established outside of the sterile ground area for the operation.

A crowd line is applicable to *any* number of uninvolved people.

Based on the sterile ground area description in paragraph 2.1.16, the crowd line **must** be outside the emergency buffer.

The crowd line **must** never be less than 50m from the operational volume.

State the position of the crowd line. (See paragraph 3.2, figures 1 and 2.)

2.1.18 Swarm for public display – crowd line marking and monitoring

Uninvolved third parties **must not** be permitted to cross the crowd line when the swarm is in flight.

Explain how the crowd line will be marked and how its observation will be enforced.

Explain how you will respond if uninvolved third parties cross the crowd line.

2.2 OSC Volume 2 – Systems

The technical requirements listed below **must** be included in Volume 2 of the OSC.

Any safety risks identified under any of these headings, **must** be mitigated to a tolerable and ALARP level.

Volume 3 of the OSC **must** explain why all safety risks identified in Volume 2 are tolerable and ALARP.

This list is not exhaustive and must be read in conjunction with CAP 722A.

2.2.1 UA type

The swarm **must** only be comprised of rotary wing UA.

State the type of UA to be used in the swarm.

2.2.2 Number of UA in the swarm

The number of UA in the swarm **must** be no more than necessary to complete the operation.

The number of UA in the swarm is important; as the number increases, so does the swarm's potential to harm people. It also increases the potential for RF interference, C2 spectrum issues and loss of control or fly-away events.

While the number of UA within the swarm will not necessarily increase the amount of energy transferred to a person if the swarm were to crash, it would affect the *likelihood* of a person being struck.

State the number of UA to be used in the swarm.

2.2.3 UA speed

The highest speed of an individual UA **must** be no greater than necessary to complete the operation.

State the highest speed of the individual UA in the swarm.

2.2.4 UA mass

The mass of an individual UA **must** be no greater than necessary to complete the operation.

State the mass, including payload, of the individual UA in the swarm.

2.2.5 UA kinetic energy

The kinetic energy of an individual UA **must** be no greater than necessary to complete the operation.

Kinetic energy is increased with higher UA speed. Kinetic energy is also increased with greater UA mass. See CAP 722A, Appendix A, Overflight of Uninvolved Third Parties for more information.

State the kinetic energy of the individual UA in the swarm at their highest speed.

2.2.6 UA size

The size of the UA **must** be no larger than necessary to complete the operation.

State the size of the individual UA in the swarm.

2.2.7 Swarm coordination protocol

The swarm **must** be effectively controlled.

State how the UA in the swarm establish and maintain communication with each other through an RF channel. For example, is it a ‘lead’ and ‘follower’ configuration, a mesh system, or a pre-defined waypoint configuration?

Describe how individual UA in the swarm avoid one another and obstacles.

2.2.8 Intra-swarm collision avoidance and movement

All UA in the swarm **must** remain separated from each other during the operation.

Explain the collision avoidance and movement co-ordination technologies between UA.

2.2.9 Whole system single points of failure

All single points of failure **must** be identified and mitigated.

State all single points of failure and explain how these points are mitigated in Volume 2 of the OSC.

2.2.10 Known failure modes

All known failure modes **must** be identified and mitigated.

State all known failure modes and explain how these are mitigated in Volume 2 of the OSC.

2.2.11 ADS-B dual frequency receiver

The remote pilot **should** use technical means to supplement visual lookout.

The remote pilot **should** be aware of other ADS-B equipped aircraft close to the operation.

An ADS-B dual frequency receiver operating on 978MHz and 1090MHz **should** be used and **must** be in the same place as the swarm.

ADS-B receivers **may** be airborne, or ground based and **must** be in the immediate vicinity of the swarm.

One ADS-B receiver **may** be used for the entire swarm.

If an ADS-B receiver is used, describe how it will be used to monitor ADS-B equipped aircraft nearby.

Describe the use of any third-party web-based application to supplement visual lookout and explain its limitations in terms of reliability and coverage.

If an ADS-B receiver is not used, explain why.

2.2.12 C2 link

An effective C2 link **must** be maintained between the command unit and the swarm.

State how a C2 link between the command unit and the swarm is assured.

Describe how the C2 link works and the risks of it being lost during the operation.

Describe all technical mitigations designed to prevent the loss of the C2 link. For example, any redundancy provided within the system through the use of independent C2 links.

2.2.13 C2 link frequency

Any interference on the C2 link frequency **must not** present an intolerable risk of the loss of the C2 link.

State which C2 frequency or frequencies will be used.

Explain how potential RF interference is assessed prior to and during the operation. A calibrated spectrum analyser or equivalent signal monitoring system **should** be used before and during flight.

Explain how the operator ensures that they are aware of any notified RF interference for the

date and time of the intended flight of the swarm.

2.2.14 C2 link signal latency

The C2 link signal latency **must** be tolerable to maintain control of the swarm.

Describe the proof that the signal latency timing within the C2 link falls within the tolerable limit.

2.2.15 GNSS

The planned flight of the swarm **must** remain within the flight volume.

GNSS **must not** be lost to the extent that the safe and effective control of the swarm cannot be maintained.

It is not a requirement to use GNSS. However, if GNSS is used the following information **must** be included:

- Describe the GNSS equipment used.
- Explain how GNSS is used in the operation and the navigational precision required.
- State the minimum number of satellites required for the operation.
- Explain how the number of satellites is monitored before and during the operation.
- Explain any use of dilution of precision indicators.

2.2.16 'Geo-caging' function

The planned flight of the swarm **must** remain within the flight volume.

A technical function which 'automatically' retains the swarm within a pre-defined airspace volume (sometimes referred to as a 'geo-caging' capability) **may** be used.

However, if such a capability is being relied upon as a safety mitigation, the following information **must** be provided:

- Describe the equipment being used to provide this capability.
- Explain how the capability is used in the operation.
- Explain how the navigational data being used accurately represents the flight volume.
- Explain how reliable it is.

2.2.17 Visual conspicuity

The swarm **must** be visually conspicuous.

If operating at night, conspicuity lighting **must** be fitted to each UA.

Display lighting **may** be used for visual conspicuity.

If the swarm is for the purpose of public display, it is accepted that some or all UA may have their conspicuity lights off or flashing for periods of time. These periods **should** be minimised, and operators **must** demonstrate how they will mitigate the safety risk to other air users during periods when some or all UA are not displaying conspicuity lighting.

Describe how periods of flight by UA that are part of a public display and are not displaying conspicuity lighting are minimised.

State the maximum distance that each individual UA can be expected to be seen using unaided eyesight (corrective spectacles **may** be used).

2.2.18 Flight termination function

A flight termination function **must** be available to stop the swarm's flight in an emergency to prevent harm to people.

Explain the flight termination function and how it ensures safe termination of the flight if required.

Explain how the flight termination function ensures the swarm will not leave the emergency buffer.

Return to Home function is not an appropriate flight termination function for swarms.

2.3 OSC Volume 3 – Safety Risk Assessment

All safety risks associated with the operation **must** be tolerable and ALARP.

The safety risk assessment must be carried in accordance with CAP 722A.

It is important to ensure that mitigations that you rely on to reduce safety risk are described in Volumes 1 and 2 of your OSC.

In Volume 3 of the OSC, you **must** explain why all safety risks identified in Volumes 1 and 2 are tolerable and ALARP.

2.4 Additional application requirements

2.4.1 Demonstration flight

A demonstration flight, observed by CAA staff, **must** be conducted.

During the application process the applicant **must** conduct a demonstration flight which will be observed by CAA staff. The demonstration flight is only required as part of the application process.

The flight **must** comply with the following requirements:

- The flight **must** be carried out in a sterile ground area.

- The flight **must** demonstrate the proposed operation and emergency procedures.
- Relevant equipment capabilities, particularly those which are being relied upon as safety mitigations, **must** be demonstrated.

2.4.2 Third country operators

All third country operators wishing to conduct swarm operations within the UK **must** apply to the UK CAA for authorisation.

Third country operators wishing to conduct swarm operations within the UK **must** already be in possession of an equivalent authorisation to operate within their parent State/State of residence.

The application **must** contain evidence, such as a letter or statement, of authorisation granted by the resident country NAA for swarm operations.

The UAS operator **must** be appropriately registered in order to conduct flying operations within the UK.

CHAPTER 3 | Additional information

3.1 Airspace

This chapter will help applicants create and visualise the airspace associated with the swarm operation.

Applicants **must** describe the airspace required for the operation within the OSC, in accordance with Chapter 2 of this document and CAP 722A.

Applicants **should** provide airspace diagrams.

3.1.1 Flight volume

The upper vertical limit of the flight volume **must** be kept as low as possible and only be as high as necessary to safely accommodate the planned swarm operation.

The flight volume **must** encompass the entire swarm and its planned movement, with sufficient buffer for any operational movement around the flight path. Consideration **should** be given to surrounding airspace, other airspace users and ground risks.

Operational movement includes UA movement for navigational changes, such as turns, and expected weather conditions.

3.1.2 Contingency volume

The contingency volume is adjacent to and surrounds the flight volume. It **must** be large enough to accommodate UA leaving, and manoeuvring to re-enter, the flight volume.

The contingency volume is established to cater for unexpected circumstances, such as manoeuvring the UA to avoid deteriorating weather conditions or other airspace users.

If any UA enters the contingency volume, or the remote pilot suspects it might happen, the contingency procedures **must** be carried out immediately and **must** result in the UA re-entering the flight volume as soon as possible. The contingency procedures **must** be stated in the OSC.

3.1.3 Operational volume

The operational volume is the zone containing the flight volume and the contingency volume.

3.1.4 Emergency buffer

The emergency buffer is airspace that is adjacent to and surrounds the operational volume.

If any UA enter the emergency buffer or the remote pilot suspects it might happen, the emergency response plan (ERP) **must** be carried out immediately.

3.1.5 Dimensions of the emergency buffer

The horizontal and vertical dimensions of the emergency buffer are dictated by two principles:

- It **must** be large enough to contain controlled manoeuvres made by the UA as part of the ERP. This includes flight termination.
- It **must** be large enough to contain the predicted flight path of a UA that leaves the contingency volume in any direction while suffering a total loss of propulsion and control.

3.1.6 Calculating the emergency buffer

The dimensions of the emergency buffer **must** satisfy both principles detailed in paragraph 3.1.5 above.

When calculating the dimensions of the emergency buffer, UAS operators **must** consider all the following points:

- The upper limit of the operational volume:
    - The horizontal dimensions of the emergency buffer **must** be at least the same as the height of the operational volume. This is the minimum distance required. This is referred to as distance 'X' in paragraph 3.2, figures 1 and 2.
- Any technical limitations and capabilities used in the ERP.
- The speed of the UA.
- The effect of wind, and therefore any subsequent drift, on the UA.
- Any other aspects of the operation that might increase the size of the emergency buffer.

3.2 VLOS swarm for public display diagrams

Note: The diagrams are not to scale

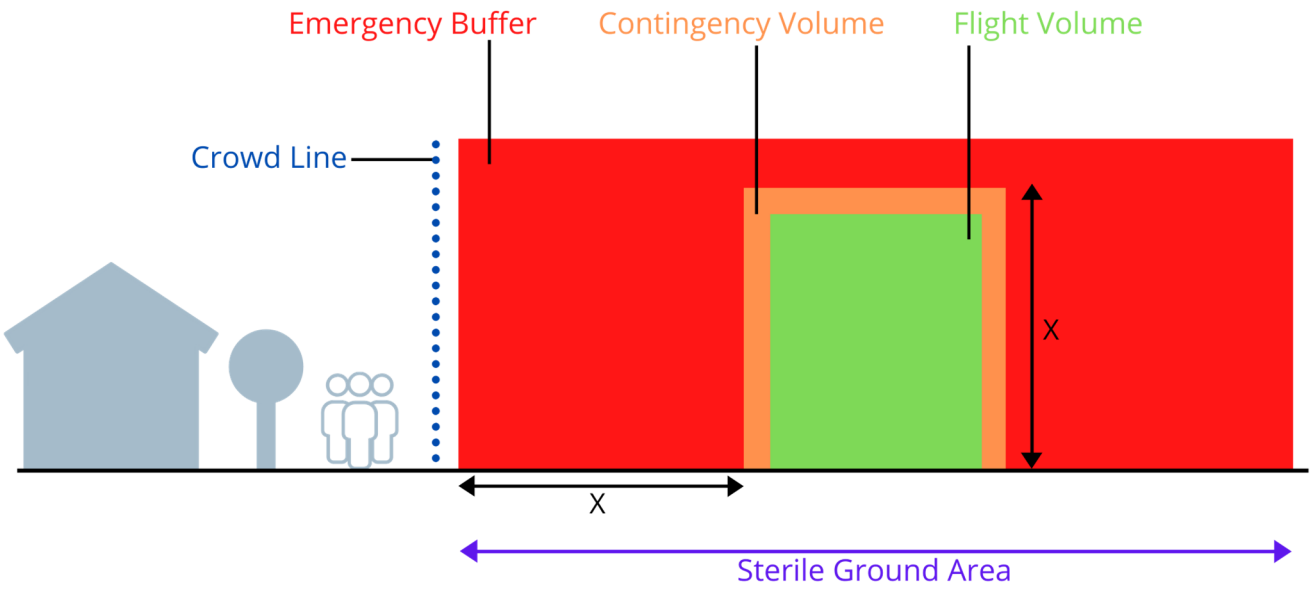

Figure 1. Side elevation view

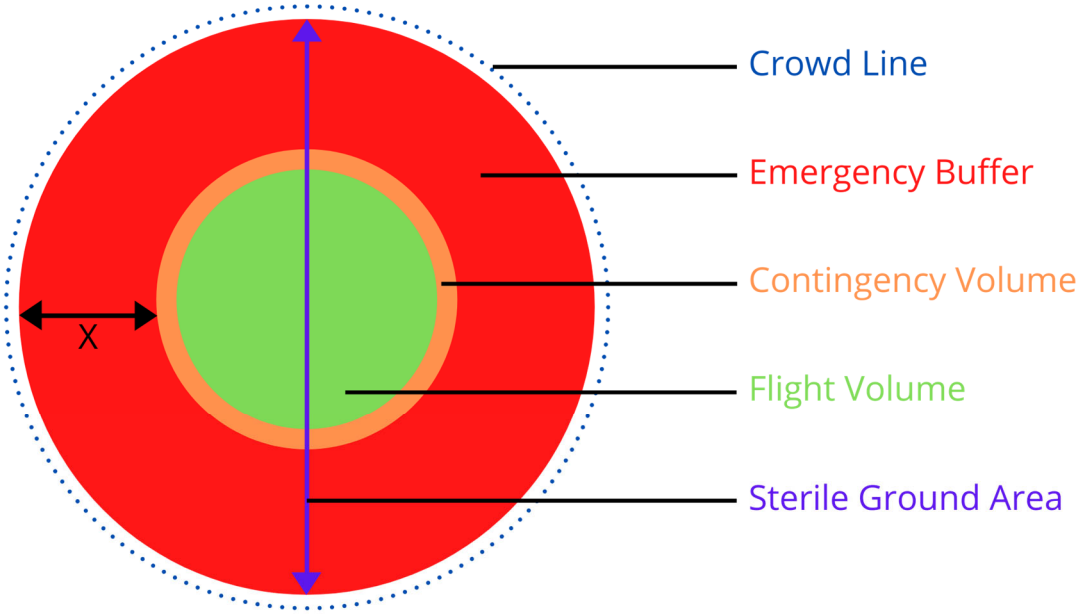

Figure 2. Plan view

3.3 Additional guidance for notifying swarm operations using form DAP 1918

If approval for a swarm operation is granted by the CAA UAS Unit, the operator **must** complete form DAP 1918 for each flight. The form **should** be filled in accordance with the instructions below and in CAP 736.

DAP 1918 is a notification form and **must** be submitted at least 28 days before the date of the event. Operators **should** factor this time into the application planning timeline.

DAP1918 can be completed online and submitted using the 'Submit Form' option on the bottom right of the form. Please note that some web browsers will not allow this action to take place and an error message could be received. If this is the case, the sponsor **should** submit a completed PDF copy to CAA Airspace Regulation Operations Team at arops@caa.co.uk.

It is important to note that form DAP 1918 and CAP 736 are being updated to include UAS swarm operations but might not be published before this CAP is issued. For that reason, additional requirements and guidance have been included here.

If DAP 1918 is still issue 01, operators **must** follow these additional instructions when completing the form:

- *Section 2, Brief Description of Event*

  The description **must** also include the number of UA in the swarm.

  The description **must** indicate if the purpose of the swarm is for aerial lighting effects. For example, 'Aerial Lighting using 50 Unmanned Aircraft in a Swarm'.

  The description **must** also include details of any periods of time when UA will not be lit, for example as part of a public display.

  See paragraph 2.1.7 for more information.

  A telephone number(s) **must** be provided so that operator and remote pilot can be contacted before and during the event.

  Telephone numbers will be used for urgent flight safety messages and might be passed to air traffic control agencies for this purpose.

- *Section 3, URL Link to Location on Webpage*

  This section **must** also include the dimensions and position of the airspace required for the swarm operation.

  The airspace information is the position and location of the flight volume, contingency volume, and emergency buffer.

  The position of the swarm **must** be stated as either an Ordnance Survey grid reference or WGS84 co-ordinates expressed in latitude and longitude.

- *Section 3, Maximum Display Height*

  The maximum height of the swarm **must** be added in this section.

  Issue 1 of the form indicates that this information is only for firework displays; however, this information is also required for swarms.

  The maximum height is the upper limit of the operational volume.

  The upper limit **must** be expressed in feet AGL.

Appendix A | Summary of requirements

Appendix A summarises the requirements listed in Chapter 2.

It **must** be read in conjunction with CAP 722A – Unmanned Aircraft Systems Operations in UK Airspace – Operating Safety Cases.

OSC Volume 1 – Operations Manual

The operational requirements listed below **must** be included in Volume 1 of the OSC.

This list is not exhaustive and must be read in conjunction with CAP 722A.

Paragraph Number and Title (Paragraph 2.1)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.1)
2.1.1 Remote pilot competence	The remote pilot(s) **must** be competent to carry out UA swarm operations
2.1.2 Support crew competence	The support crew **must** be competent to support UA swarm operations
2.1.3 Line of sight	The swarm operation **must** be carried out within VLOS
2.1.4 Dimensions of the flight volume	The planned flight of the swarm **must** remain within the flight volume The upper limit of the flight volume **must** be kept as low as possible and only be as high as necessary to accommodate the planned flight of the swarm The horizontal dimensions of the flight volume **must** be sufficient to accommodate the planned flight of the swarm
2.1.5 Swarm height	The height of the swarm **must** be monitored and accurately measured

Paragraph Number and Title (Paragraph 2.1)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.1)
2.1.6 Airspace	Appropriate airspace **must** be used for the swarm operation
2.1.7 Notification	All swarm flights **must** be notified in advance to CAA Airspace Regulation Operations (AR Ops)
2.1.8 Weather conditions	The swarm operation **must** only be conducted in the appropriate weather conditions
2.1.9 Go/no-go criteria	Go/no-go and abort criteria **must** be clearly defined for the swarm operation
2.1.10 Emergency abort	The decision to abort the swarm **must** be made quickly and reliably enough, in response to an emergency, to prevent harm to people
2.1.11 Operating procedures	Operating procedures **must** be clearly defined for the swarm operation
2.1.12 Illumination of take-off, landing and nominated recovery areas	The take-off, landing and nominated recovery areas **must** be sufficiently illuminated
2.1.13 Insurance	The insurance policy **must** provide adequate cover for swarming operations
2.1.14 Projection or dropping of articles	The safety risks associated with the projection or dropping of articles **must** be tolerable and ALARP
2.1.15 Overflight of uninvolved third parties	The swarm **must not** overfly any uninvolved third parties
2.1.16 Swarm for public display – sterile ground area	A sterile ground area **must** be in place for the operation
2.1.17 Swarm for public display – crowd line position	A crowd line **must** be established outside of the sterile ground area for the operation

Paragraph Number and Title (Paragraph 2.1)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.1)
2.1.18 Swarm for public display – crowd line marking and monitoring	Uninvolved third parties **must not** be permitted to cross the crowd line when the swarm is in flight

OSC Volume 2 – Systems

The operational requirements listed below **must** be included in Volume 2 of the OSC.

This list is not exhaustive and must be read in conjunction with CAP 722A.

Title (Paragraph 2.2)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.2)
2.2.1 UA type	The swarm **must** only be comprised of rotary wing UA
2.2.2 Number of UA in the swarm	The number of UA in the swarm **must** be no more than necessary to complete the operation
2.2.3 UA speed	The highest speed of an individual UA **must** be no greater than necessary to complete the operation
2.2.4 UA mass	The mass of an individual UA **must** be no greater than necessary to complete the operation
2.2.5 UA kinetic energy	The kinetic energy of an individual UA **must** be no greater than necessary to complete the operation
2.2.6 UA size	The size of the UA **must** be no larger than necessary to complete the operation
2.2.7 Swarm control protocol	The swarm **must** be effectively controlled

Title (Paragraph 2.2)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.2)
2.2.8 Intra-swarm collision avoidance and movement	All UA in the swarm **must** remain separated from each other during the operation
2.2.9 Whole system single point of failure	All single points of failure **must** be identified and mitigated
2.2.10 Known failure modes	All known failure modes **must** be identified and mitigated
2.2.12 C2 link	An effective C2 link **must** be maintained between the command unit and the swarm
2.2.13 C2 link frequency	Any interference on the C2 link frequency **must not** present an intolerable risk of the loss of the C2 link
2.2.14 C2 link signal latency	The C2 link signal latency **must** be tolerable to maintain control of the swarm
2.2.15 GNSS	The planned flight of the swarm **must** remain within the flight volume
2.2.16 'Geo-caging' function	The planned flight of the swarm **must** remain within the flight volume
2.2.17 Visual conspicuity	The swarm **must** be visually conspicuous
2.2.18 Flight termination function	A flight termination function **must** be available to stop the swarm's flight in an emergency to prevent harm to people

OSC Volume 3 – Safety Risk Assessment

In Volume 3 of the OSC, you **must** explain why all safety risks identified in Volumes 1 and 2 are tolerable and ALARP.

The safety risk assessment must be carried in accordance with CAP 722A.

Title (Paragraph 2.3)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.3)
Safety risk assessment	All safety risks associated with the operation **must** be tolerable and ALARP

Additional application requirements

Title (Paragraph 2.4)	Basic requirement for all rotary wing VLOS swarms (Paragraph 2.4)
2.4.1 Demonstration flight	A demonstration flight, observed by CAA staff, **must** be conducted
2.4.2 Third country operators	All third country operators wishing to conduct swarm operations within the UK **must** apply to the UK CAA for authorisation Third country operators wishing to conduct swarm operations within the UK **must** already be in possession of an equivalent authorisation to operate within their parent State/State of residence